MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

AN APPROACH FOR STUDYING THE CREEP/ SLIDING BEHAVIOR OF PLANAR METAL-SILICON INTERFACE

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There has been considerable recent interest in interfacial sliding during creep of multi-phase materials. The effect of interfacial creep is crucial for the deformation of metal-matrix composites and thin film systems, where the isostrain condition between the constituent components is often violated. An experimental approach has been developed to investigate the deformation kinetics of planar interfaces, using a double-shear specimen geometry where the interfaces are loaded in shear. In addition to shear stresses, the apparatus is capable of applying normal stresses (tension or compression) on the interface. In the experimental arrangement, the relative displacements of the constituents at the top and bottom of the specimen are measured independently with high precision using a resistance gauge and a capacitance sensor, respectively. The experimental set-up is suitable for both constant displacement-rate and constant-load creep tests, and can be operated up to a temperature of 500°C. In the current study, preliminary creep tests were conducted on planar aluminum-silicon interfaces prepared by diffusion bonding in argon atmosphere at 565°C. During the tests, the interfaces were subjected to nominally constant shear stresses ranging from 0.8-2 MPa, with the test temperatures ranging from 100-200°C. In all cases, the interface was found to slide via a time-dependent relaxation mechanism, indicating the suitability of the proposed test for studying interfacial sliding. Further studies are needed to determine the mechanistic details of interfacial sliding.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Composite, Planar Interface, Interfacial Sliding, Creep

NUMERICAL STUDY FOR GLOBAL DETECTION OF CRACKS EMBEDDED IN BEAMS

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Damage reduces the flexural stiffness of a structure, thereby altering its dynamic response. Considerable effort has been put into obtaining a correlation between the changes in modal parameters and the location and amount of the damage within the structure. Most numerical research employed elements with reduced beam stiffness to simulate damage in the beam. This approach to damage simulation neglects the non-linear effect that a crack has on the structural dynamic response. In the present study, finite element modeling techniques are utilized to directly represent an embedded crack. The results of the dynamic analysis of the present model are then compared to the results of the dynamic analysis of the reduced modulus finite element model. Different modal parameters are investigated to determine the most sensitive

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indicator of damage and its location. Nonlinear effects, such as crack closure and opening, of an embedded crack on the structural dynamic response were also studied from transient nonlinear analysis. The modeling technique is then applied to sandwich composite beams with simulated delamination to investigate damage detection techniques through the use of damping caused by frictional dissipation of energy on the crack surface.

DOD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Finite Element Analysis, Modal Analysis, Non-destructive Damage Detection, Composite Materials

ACTIVE VIBRATION CONTROL METHOD FOR SPACE TRUSS USING PIEZOELECTRIC ACTUATORS AND FINITE ELEMENTS

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This thesis created an analytical model for active vibration control of the NPS space truss using ANSYS. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment at its extremities. With the use of a dSPACE data acquisition and processing system, quartz force transducer and piezoelectric actuator, active controls using an integral plus double integral control law were used to damp out the vibrations caused by a linear proof mass actuator. Vibration reductions on the order of 15-20 dB were obtained with experiment.

The ANSYS finite element model used SOLID5 elements to model the piezoelectric characteristics and ANSYS Parametric Design Language to provide for an iterative approach to an active controls analysis. Comparative data runs were performed with the ANSYS model to determine its similarity to experiment. The analytical model produced power reductions of 18-22 dB, demonstrating the ability to model the control authority with a finite element model. This technique can be used and modified to enhance its flexibility to many types of controls and vibration reduction applications. An analytical model for active control of the NPS space truss using MATLAB/Simulink was also developed as an alternative to the ANSYS model.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Active Vibration Control, Piezoceramic Actuators, ANSYS, Finite Element Method

FACTORS AFFECTING THE STRENGTH AND TOUGHNESS OF ULTRA-LOW CARBON STEEL WELD METAL

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The factors that affect strength and toughness of ten ultra-low carbon steel weld samples (HSLA-80 and HSLA-100), welded using the gas metal arc welding (GMAW) process and new ultra-low carbon consumable electrodes, were studied. The analysis was confined only to the weld metal, and the base metal was not considered. Analysis methods included optical microscopy, scanning electron microscopy, and transmission electron microscopy. Energy dispersive x-ray analysis was performed in the transmission electron microscope to analyze the chemical composition of non-metallic inclusions.

The microstructure was found to be primarily granular ferrite with some primary ferrite, bainite, and martensite. Very little acicular ferrite was found (< 18 %). Because of this, to get the best mechanical properties in the weld, the size and volume fraction of non-metallic inclusions needs to be minimized. This can be accomplished by minimizing the amount of oxygen while increasing the amount of titanium and aluminum in the weld metal.

EDX analysis revealed that the non-metallic inclusions were multi-phase particles with two predominant phases: a TiO-MnO phase and a MnO-SiO_2-Al_2O_3 phase. Copper-sulfide caps were also found on the surface of some inclusions. This inclusion chemistry is typical of what is found in welding HSLA steel.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: HSLA-80, HSLA-100, Gas Metal Arc Welding, Ultra-Low Carbon Steel, Non-Metallic Inclusions